

## **TITLE**

### **SCALABLE QAM SYSTEM AND METHOD**

#### **BACKGROUND OF THE INVENTION**

##### **Field of the Invention**

5       The present invention relates to a quadrature amplitude modulation (QAM) communication technique, and more specifically, to a scalable QAM communication method, transmitter, and communication system.

##### **Description of the Related Art**

10       The QAM modulation technique is frequently implemented in networks with share media, wherein the downlink signals are broadcast to network clients. Examples of such network are digital cable modem, digital television, and 802.16 broadband wireless system. The system service provider broadcasts signals  
15 to each network client, however, the signal quality received by each client is different, as the clients are located at different positions and are under different environmental condition. In order to maintain a low uncoded transmission bit error rate, the service provider uses a lower level QAM, for example, 64QAM to  
20 modulate the signals. The bandwidth efficiency of the downlink channel is thus restricted by the level of QAM used for modulation.

Figure 1 shows the topology of the network in the related art which transmits data to shared media, and broadcasts signals  
25 over the downlink channel. A transmitter 102 is usually the service provider of the communication system, and the transmitter 102 connects clients 104, 106, and 108 through a network 100. The transmitter 102 broadcasts a QAM modulated

signal to the network 100, and the clients 104, 106, and 108 receive the QAM modulated signal sent by the transmitter 102 through the network 100. The signal to noise ratio (SNR) of the signal received by the client 104 is 25dB, thus the client 104  
5 can only receive and demodulate the 64QAM modulated signal. The SNR of the signal received by the client 106 is 30dB, enabling the client 106 to receive both 64QAM and 256QAM modulated signals. Furthermore, if the SNR of the signal received by the client 106 is 35dB, the client 106 can receive 64QAM, 256QAM,  
10 and 1024QAM modulated signals as the client 106 is able to demodulate all these signals correctly. The transmitter 102 in this case, however, can only modulate the 64QAM signal in order to allow all the clients 104, 106, and 108 to be able to receive and demodulate the modulated signal correctly.

#### 15 SUMMARY OF THE INVENTION

The object of the present invention is to provide a scalable QAM communication technique for improving the network transmission rate, overcoming the variable interference of the transmission channel, and maintaining a reasonable low  
20 demodulation error rate.

In order to achieve these objects, the present invention provides a scalable QAM communication technique in which a transmitter broadcasts a single high level efficiency QAM modulated signal wherein signal transmission is accomplished by  
25 distributing the bit data in different bit positions through combining the scalable frame structure control of the media access control (MAC) layer and the bitmap technique of the physical layer. Each downlink client can decide to receive all the data on the bit plane or only a portion of the data on certain

bit positions according to the transmission quality of the received signal.

The scalable QAM communication technique disclosed in the present invention includes a scalable QAM communication method,  
5 a transmitter, and a communication system. The scalable QAM communication method comprises distributing bit data in different bit positions for transmission, combining the bit data in different bit positions, modulating the combined signal according to a QAM technique, and broadcasting the QAM modulated  
10 signal over a channel.

The scalable QAM transmitter of the present invention comprises a media access controller, encoders, and a bitmap device. The media access controller sends different types of MAC messages, the encoders generate different types of bit data  
15 using different types of channel encoding methods to encode the different types of MAC messages, and the bitmap device assigns the different types of bit data to different bit positions, and combines the data of different bit positions to generate a component signal.

20 Furthermore, the scalable QAM communication system of the present invention comprises a transmitter and a plurality of clients. The transmitter distributes bit data in different bit positions for transmission, combines data on the different bit positions, modulates the combined signal using the QAM  
25 technique, and then broadcasts the QAM modulated signal to a channel. The clients then receive the signal from the channel, and each client determines whether to demodulate all data on the bit plane or just certain bit positions according to the transmission quality of the received signal.

### BRIEF DESCRIPTION OF THE DRAWINGS

The present invention can be more fully understood by reading the subsequent detailed description in conjunction with the examples and references made to the accompanying drawings, wherein:

Fig. 1 illustrates the network topology of the related art which has shared media and broadcasts signals over the downlink channel;

Fig. 2a illustrates the network topology of the scalable QAM communication system according to the embodiment of the present invention;

Fig. 2b is a flowchart showing the client registration procedure according to the embodiment of the present invention;

Fig. 3 is a block diagram illustrating the system structure of the scalable QAM communication system according to the embodiment of the present invention;

Fig. 4 is a constellation diagram showing the data distribution of QPSK, 16QAM, and 64QAM modulation.

### DETAILED DESCRIPTION OF THE INVENTION

The scalable QAM communication system disclosed in the present invention can be implemented in a digital cable modem, interactive digital satellite/terrestrial/cable set-top box/digital TV, or 802.16 broadband wireless communication system. This communication system applies to a network with shared media, and the system transmits signals by broadcasting over the downlink channel. As shown in Figure 2a, Figure 2a illustrates the network topology constructed by the scalable QAM communication system according to the embodiment of the present invention. A transmitter 202 connects to clients 204a, 204b, ...,

204n through a network 200. The clients 204a~204n receive a broadcast signal, unicast signal, or multicast signal from the transmitter 202 after completing the registration procedure. In the present embodiment, the SNR of the signal received by the client 204a is 25dB, thus the client 204a can only correctly demodulate the 64QAM modulated signal. The SNR of the signals received by the client 204b~204(n-1) are 30dB, thus these clients can correctly demodulate both the 64QAM and 256QAM modulated signals. The SNR of the signal received by the client 204n is 35dB, representing that the client 204n can precisely demodulate all the 64QAM, 256QAM, and 1024QAM modulated signals. Figure 2b shows a flowchart of the registration procedure of a client according to the embodiment of the present invention. The transmitter 202 first broadcasts the registration signal for the channel 200 (step S212), the registration signal is the highest level QAM modulated signal the system is capable of, which in the present embodiment, is the 1024QAM modulated signal. Moreover, the registration data is placed in the bit position with the most significant bit (MSB).

The clients desiring registration determine the type of QAM modulated signal to receive, as well as the demodulation method (step S214) according to the transmission quality of the registration signal. For example, the signal received by a client 204 desiring registration has an SNR of 25dB, thus the client 204 can only demodulate 64QAM modulated signal correctly. Although the registration signal is a 1024QAM modulated signal, the client 204a can still obtain registration data because the registration data is on the MSB bit position.

The clients desiring registration then send an uplink request and demodulation method to the transmitter 202 (step

S216), for example, the client 204a desiring registration transmits an uplink request to the transmitter 202, as well as notifying the transmitter 202 that the demodulation method used is the 64QAM method.

5       The transmitter 202 builds a client database when receiving the uplink request from the client in order to complete client registration (step S218).

10       In Figure 2a, the transmitter 202 sends packets to the client using the media access control (MAC) message with the corresponding type. Refer to Figure 3 for further descriptions of sending the modulated signal to the registered client 204a~204n by the transmitter 202.

15       Figure 3 illustrates the system structure of the scalable QAM communication system according to the embodiment of the present invention. As shown in the diagram, the transmitter 202 comprises a media access controller 302, two sets of forward error correction (FEC) encoders 304a~304m and 314a~314m, two sets of first in first out (FIFO) registers 306a~306m and 316a~316m, two bitmap devices 308 and 318, a QAM modulator 310, and an antenna 320. Each client 204 comprises an antenna 350, a QAM demodulator 360, an adaptive slicer 362, a de-bitmap device 364, a multi-mode FEC decoder 366, and a media access controller 368.

25       The media access controller 302 of the transmitter 202 sends M different types (type 1 to type M) of media access control (MAC) messages. The different types of MAC messages control and arrange different data payloads according to different MAC headers.

30       The different types (type 1 to type M) of MAC messages are sent to the FEC encoders 304a~304m and 314a~314m for channel

encoding. After channel encoding, the bit data output from the FEC encoders 304a~304m is then sent to the corresponding FIFO registers 306a~306m and the bitmap device 308. The bitmap device 308 assigns the different types of bit data to different bit positions, and combines data of different bit positions to generate an I component signal  $T_I$ . Conversely, the bit data output from the FEC encoder 314a~314m is sent to the corresponding FIFO register 316a~316m and the bitmap device 318. The bitmap device 318 assigns the different types of bit data to different bit positions, and combines data of different bit positions to generate a Q component signal  $T_Q$ .

The highest level QAM modulated signal broadcast by the transmitter 202 is assumed to be a 64QAM signal (i.e.  $M=3$ ) in the following description. As shown in Figure 4, when considering all three bit positions of the I axis and the Q axis, the first level of the 64QAM data can be composed by matching the bit data of the type 1 MAC message to the bit position of the MSB, and the bit data of the type 2 MAC message to the bit position of the second MSB, and the bit data of the type 3 MAC message to the bit position of the least significant bit (LSB). The second level of the 64QAM data can be composed by matching the first two MSB bits of the I axis and the Q axis, and the third level of the data can be composed by matching the first MSB bit of the I axis and the Q axis. The description of Figure 4 also explains the operation of the bitmap device 308 in Figure 3.

Data located in different bit positions generated by the bitmap devices 308 and 381 require different MAC messages for controlling and scheduling. If the highest level of the QAM modulated signal is a 64QAM signal, the bit data of the type 1 MAC message corresponds to the bit positions of the MSB in the

bitmap device 308. Thus, bit data of the type 1 MAC message is broadcast to all registered clients or unicast to clients able to demodulate QPSK, 16QAM or 64QAM modulated signals. The bit data of the type 2 MAC message corresponds to the bit positions  
5 of the second MSB, thus the bit data of the type 2 MAC message is the data unicast to clients who can demodulate the 16QAM or 64QAM modulated signals correctly. Furthermore, the bit data of the type 3 MAC message corresponds to the bit positions of the LSB, thus the data of the type 3 MAC message is the data for  
10 clients with SNR high enough to demodulate the 64QAM modulated signal.

QAM modulator 310 receives the I component signal  $T_I$  and the Q component signal  $T_Q$ , and modulates  $T_I$  and  $T_Q$  according to the QAM modulation technique. The antenna 320 transmits the  
15 quadrature amplitude modulated signal on the channel 330.

The QAM demodulator 360 of the client 204 first demodulates the signal received by the antenna from the channel 330 into an I component symbol  $R_I$  and a Q component symbol  $R_Q$ . In the case of 64QAM, the I component symbol  $R_I$  and the Q component symbol  
20  $R_Q$  can be expressed by three bits, and the bit expression manner of the I component symbol  $T_I$  and the Q component symbol  $T_Q$  in the client 204 is the same as the I component symbol  $T_I$  and the Q component symbol  $T_Q$  in the transmitter 202. The I component symbol  $R_I$  and the Q component symbol  $R_Q$  are sent to the de-bitmap  
25 device 364 after the adaptive slicer 362. The de-bitmap device 364 partitions each bit in the I component symbol  $R_I$  and the Q component symbol  $R_Q$  according to the bit position of each bit.

The multi-mode FEC decoder 366 determines whetherto demodulate all data on the bit plane or only a portion of the  
30 data on certain bit positions according to the transmission

quality of the received signal. If the signal received by the client 204 has a high SNR, the client 204 can precisely demodulate all type 1, type 2, and type 3 MAC messages. For example, the SNR of the signal must be approximately 25dB when  
5 the 64QAM modulated signal is chosen to be the highest level QAM modulated signal. If the signal received by the client 204 has a slightly lower SNR, the client 204 is able to demodulate type 1 and type 2 MAC messages with an acceptable bit error rate. If the SNR of the received signal is lower however, the client 204  
10 can only demodulate the type 1 MAC message. In the other words, the first level which is also the complete 64QAM data can be demodulated by the type 1, type 2, and type 3 MAC messages, the second level data can be demodulated by the type 1 and type 2 MAC messages, and the third level data can only be demodulated  
15 by the type 1 MAC message. The media access controller 368 receives the demodulated MAC message and obtains the data payload therein.

To conclude, the scalable QAM communication technique disclosed in the present invention provides a modulation method  
20 comprising a transmitter for broadcasting a single high level QAM modulated signal, and combines the scalable frame structure control of the MAC layer and the bitmap method of the physical layer to distribute the bit information in different bit positions for transmission. Each client can decide to receive  
25 all the data on the bit plane or only a portion of the data on certain bit positions according to the transmission quality of the received signal.

By implementing this scalable QAM communication technique, all clients are able to obtain data with a low bit error rate  
30 by trading off the transmission bit rate. The system implemented

the present invention can achieve robust transmission as well as maintaining a better bandwidth efficiency (bits/s/Hz).

By implementing the technique of the present invention in the cable system, both the source and the channel are scalable, hence the service provider can provide transmission services in a more efficient manner. If the existing scalable source of the cable system implements the scalable QAM technique of the present invention, the service provider is able to provide each client with a different class of service, for example, multi-resolution digital video. Different classes of sources combined with the present invention allows service providers to distribute different services to each client, for example, a portion of the bits are used to carry digital video data, while another portion carries information for Voice over Internet Protocol (VoIP) or video conference data.

Finally, while the invention has been described by way of example and in terms of the above, it is to be understood that the invention is not limited to the disclosed embodiment. On the contrary, it is intended to cover various modifications and similar arrangements as would be apparent to those skilled in the art. Therefore, the scope of the appended claims should be accorded the broadest interpretation so as to encompass all such modifications and similar arrangements.